



emchain

February 23, 2011

Abstract

Generate the EPIC-MOS event list product.

1 Instruments/Modes

| Instrument | Mode |
|------------|-----------------|
| EPIC MOS | IMAGING, TIMING |

2 Use

| | |
|----------------------|-----|
| pipeline processing | no |
| interactive analysis | yes |

3 Description

The **emchain** script chains and loops over all first-level EPIC MOS tasks to produce event lists for all exposures, ready to be exported as PPS products.

3.1 Generalities

By default all events flagged for rejection during the chain are physically removed from the output file (to save space) except those **OUT_OF_FOV** (useful for cosmic-ray background subtraction) and **REJECTED_BY_GATTI** (used for proton flare rejection). To keep all events in output set **rejectbadevents=N**. To use a different mask on **FLAG** set **rejectionflag** to another hexadecimal value (binary flags are described in **evatt**, and in the header of the **EVENTS** table of the event lists).

For later imaging analysis selecting with **#XMMEA_EM** is advised. For accurate spectral analysis, selecting with **#XMMEA_SM** is advised. This removes all flagged events except those flagged only as **CLOSE_TO_DEADPIX**. Using the stricter selection '**FLAG == 0**' is in theory even better in terms of spectral reliability, but in practise it makes little difference and can reject a sizable fraction of events (several entire columns per CCD are declared as DEAD).



All text output is sent to standard error, and may be redirected to a file (very useful to investigate problems). It is good practice to look at the warnings sent by the tasks and **emchain** itself. If the SAS_VERBOSITY environment variable is set to 1, **emchain** will tell which tasks it called. If SAS_VERBOSITY is set to 4 (suggested value), its constituent tasks will provide useful information. Larger values of SAS_VERBOSITY may result in large output files. If SAS_VERBOSITY=0, **emchain** will be mute, except for warnings and error messages.

All files are recognized by their name. Input files are looked for in the directory entered via the **odf** parameter or the SAS_ODF environment variable, which must also contain the general ODF files (attitude, time, summary file). Output files are created in the current directory. Intermediate files are removed at the end, unless **keepintermediate**=Y or an error occurred. Intermediate and output files are overwritten unless **clobber**=Y.

If one constituent task ends in error, **emchain** will continue anyway with the next CCD, exposure or instrument unless **stoponerror**=Y.

3.2 Main loop

The main subroutine (processOdf, Fig 1) loops over all exposures and instruments (MOS1/MOS2) present in the input directory (looking for event list files).

If **withatthkgen** is true or if the tracking history file does not exist already, **atthkgen** is run first. **tabgtigen** is run on the output to generate the attitude GTI. The tolerance on attitude variations may be modified via **atttol**. **hkgtigen** is run if the HK GTI does not exist already. Those GTI files are not applied by default, they are generated for information. They can be applied by setting **filteratt**=Y and/or **filterhk**=Y. They are then merged with the user GTI (if **ingtiset** is set) into the external GTI used by **emframes**.

processOdf creates one (or two, if a CCD is operated in TIMING mode) event list for every selected exposure, from all relevant ODF material and (if they exist) the good time intervals generated by **tabgtigen** and the list of bad pixels (from the CCF or produced internally).

In a first step it loops over all CCD/nodes, calling in sequence, as shown in Fig 2:

1. **emframes** on the auxiliary file, the events file and the external GTI file (if any), creating a frame file as expected by **emevents** and a CCD/node specific GTI file which will be reinjected in the final call to **evselect**.
2. **badpix** on the events list, adding the BADPIX extension. If a bad pixels file exists, it is used instead of the CAL calls for the non-uplinked bad pixels, (*i.e.* **badpix** is called with **getuplnkbadpix**=Y **getotherbadpix**=N **getnewbadpix**=Y).
3. **emevents** on the events list, the offset/variance file and the frame file, creating a new events list which will be propagated through **attcalc** and **emenergy** to **evlistcomb**.
4. **gtialign** on the external GTI file and the events file, then **gtimerge** to merge the resulting aligned GTI and the CCD/node specific GTI.
5. **attcalc** on the new events list, filling the X/Y columns.
6. **emenergy** on the new events list, filling the FLAG, PHA and PI columns.

By default position, energy and time of each photon are randomised within their respective bins (one CCD pixel for position, one ADU for energy, one frame for time).

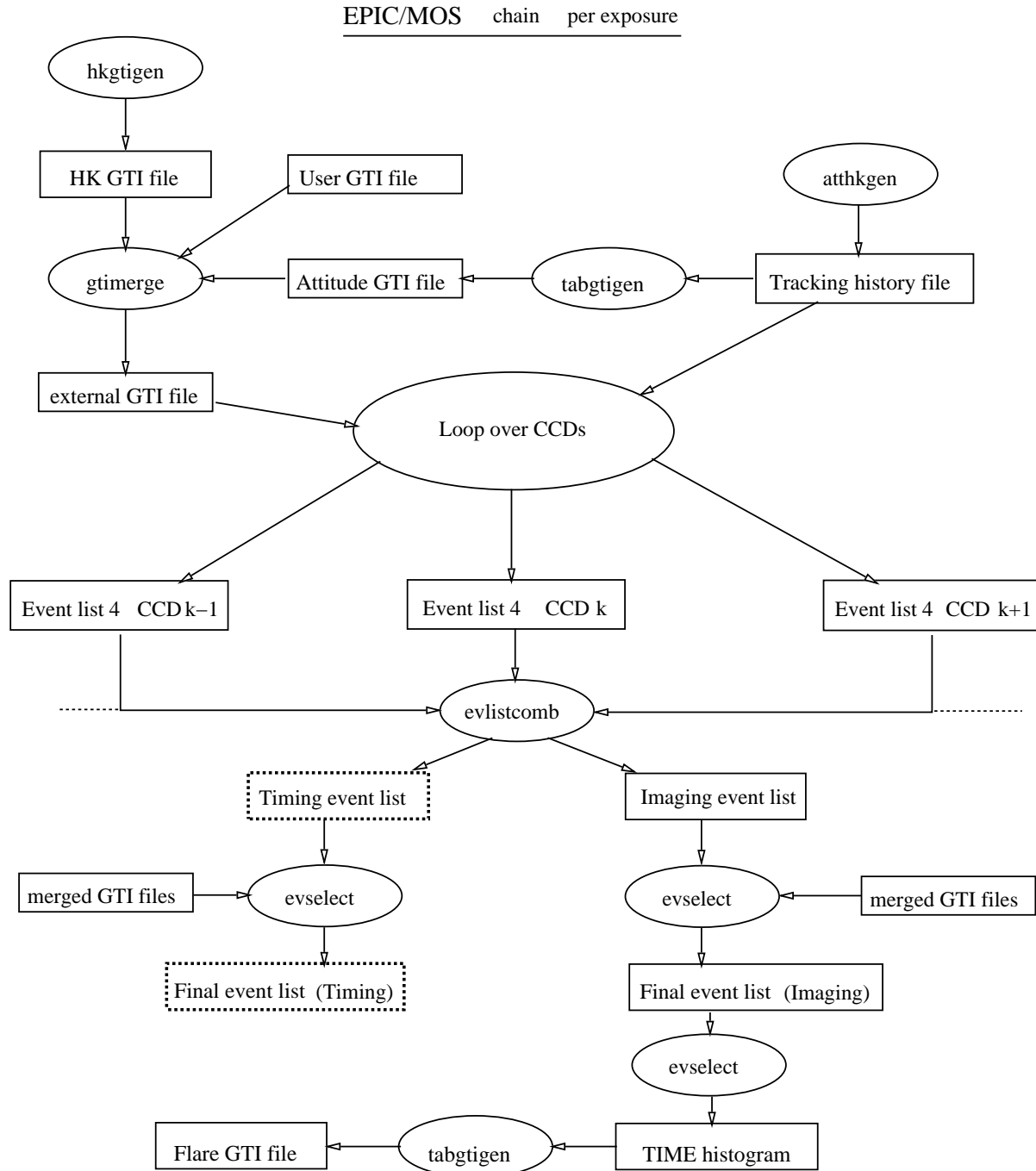


Figure 1: Organisation of the EPIC-MOS chain: merging the event lists. The files in boldly dashed boxes are used (or produced) if they exist. The files in simply dashed boxes are options of the individual tasks not used in the current chain.



EPIC/MOS chain per CCD

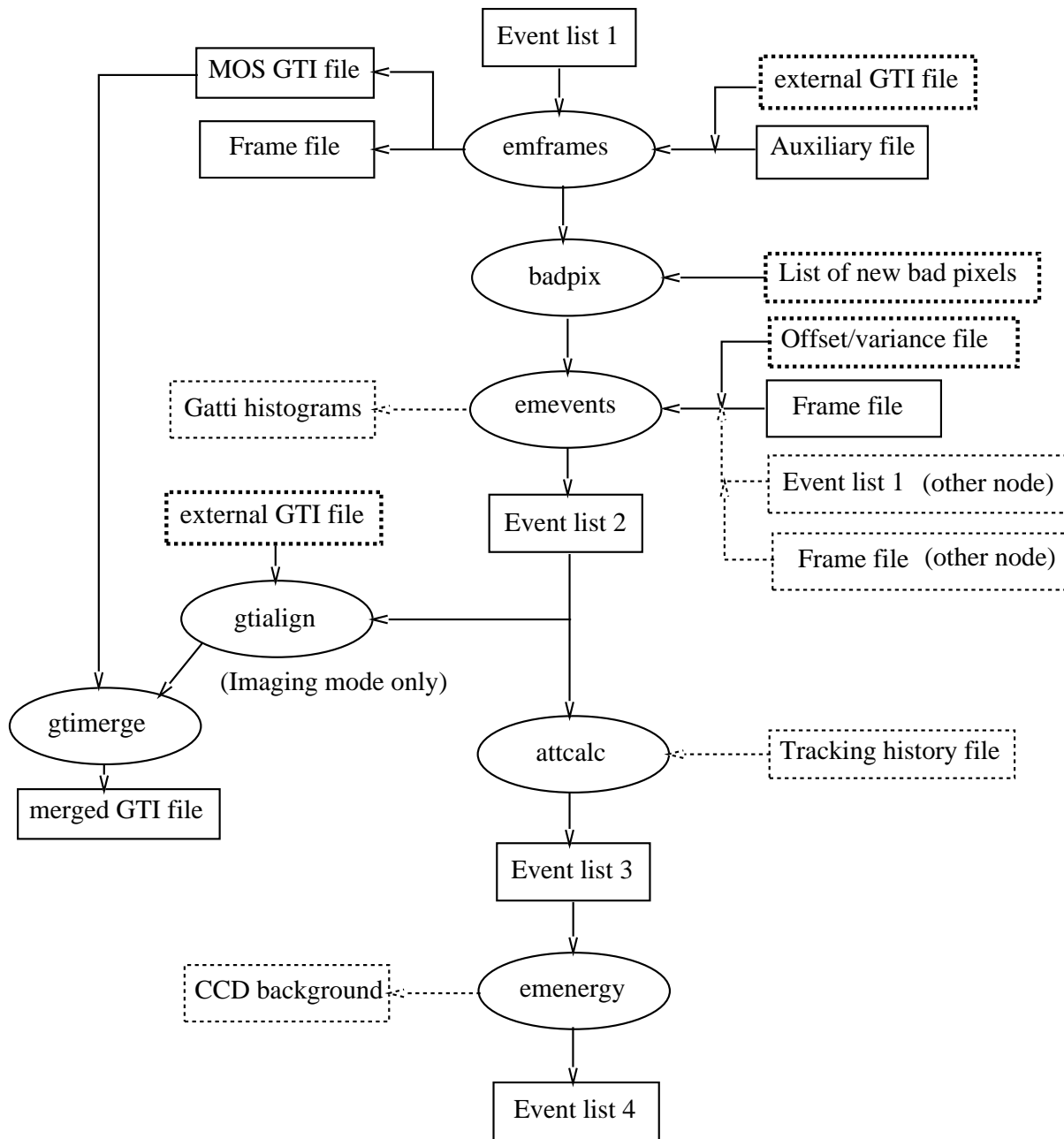


Figure 2: Organisation of the EPIC-MOS chain at CCD/node level with file inputs. Same conventions as in Fig 1



Then (Fig 1) all the event list files created (one per CCD/node) are merged by **evlistcomb**, creating one events list per mode (IMAGING, TIMING). Finally **evselect** is called on the resulting events list(s), with (CCDNR== $\$node\ccd) && GTI(merged GTI file,TIME) for all CCD/nodes. The list of calibration files used to analyse the data is added to the output files as a **CALINDEX** extension.

3.3 Flare rejection

If **makeflaregti=Y**, for all merged files (*MIEVLI*), an additional call to **evselect** (Fig 1) produces a light curve of single events from CCDs in Imaging mode flagged with **REJECTED_BY_GATTI** (with actual energy above 14 keV), with time bins defined by **flaretimebin** (if that time bin is too small to give reasonable statistics per bin, it will be increased automatically). This is aimed at finding efficiently periods of flaring activity when the focal plane is illuminated by low-energy protons. Those are mostly singles and are not cut-off by the mirror efficiency above 10 keV (contrary to astronomical sources). The result is divided by the area of the external CCDs within the field of view, and expressed in cts/ks/arcmin^2 . A fractional exposure column **FRACEXP** accounts for incomplete time bins.

If **globalflare=Y** (default), timeseries are built for all MOS event lists in the current directory, then summed together (the **ERROR** columns are summed quadratically) to build a single global timeseries. This allows to apply the same GTI to both MOS instruments, and to improve the statistics in the timeseries.

This light curve is sent to **tabgtigen** which selects all intervals when the number of cts/ks/arcmin^2 is lower than **flaremaxrate**, and produces a Good Time Intervals file. This file is filtered to avoid intervals only one **flaretimebin** long, which are usually negative fluctuations during a moderately strong flare. This file is NOT applied to the events list, unless **applyflaregti=Y**.

The quiet level is around $0.8 \text{ cts/ks/arcmin}^2$. The default value of **flaremaxrate** is conservative (to avoid rejecting too many intervals) and should be all right in most situations. The default value of **flaretimebin** is such that it covers an integer number of frames (20). It should not be chosen too small if **TIME** is not randomised (no 'T' option in **randomize**).

If **applyflaregti=Y**, the resulting Good Time Intervals are applied only if they total more than 10% of the exposure time. Otherwise the events list is left unscreened. This applies in particular to the bad pixels detection (Sect. 3.4).

3.4 Bad pixels detection

In most cases relying on the bad pixels registered in the CCF is not enough. This is because the CCF stores only the bright pixels of relatively high occurrence, but bright pixels at a low level may be a nuisance as well.

If **badpixfindalgo=EM** (default) or **EP**, the whole analysis of one exposure (Fig 1) is run first with **emevents** and **emenergy** in a simplified mode, and skipping **badpix** and **attcalc**. Then one of two bad pixel finding algorithms is called (Fig 3), depending on **badpixfindalgo**.

- If **badpixfindalgo** is set to 'EP', **badpixfind** is called. This is a conservative algorithm which will find clear-cut bright pixels or columns.
- If **badpixfindalgo** is not set or set to 'EM', **embadpixfind** is called. This is a more sensitive algorithm which will detect bad pixels, segments of columns or rows down to the statistical limit of Poisson counts.

If part of the exposure is affected by flares, this can seriously reduce the power of the bad pixels search (flares act as noise for the bad pixels and make detecting them more difficult). Therefore an intermediate

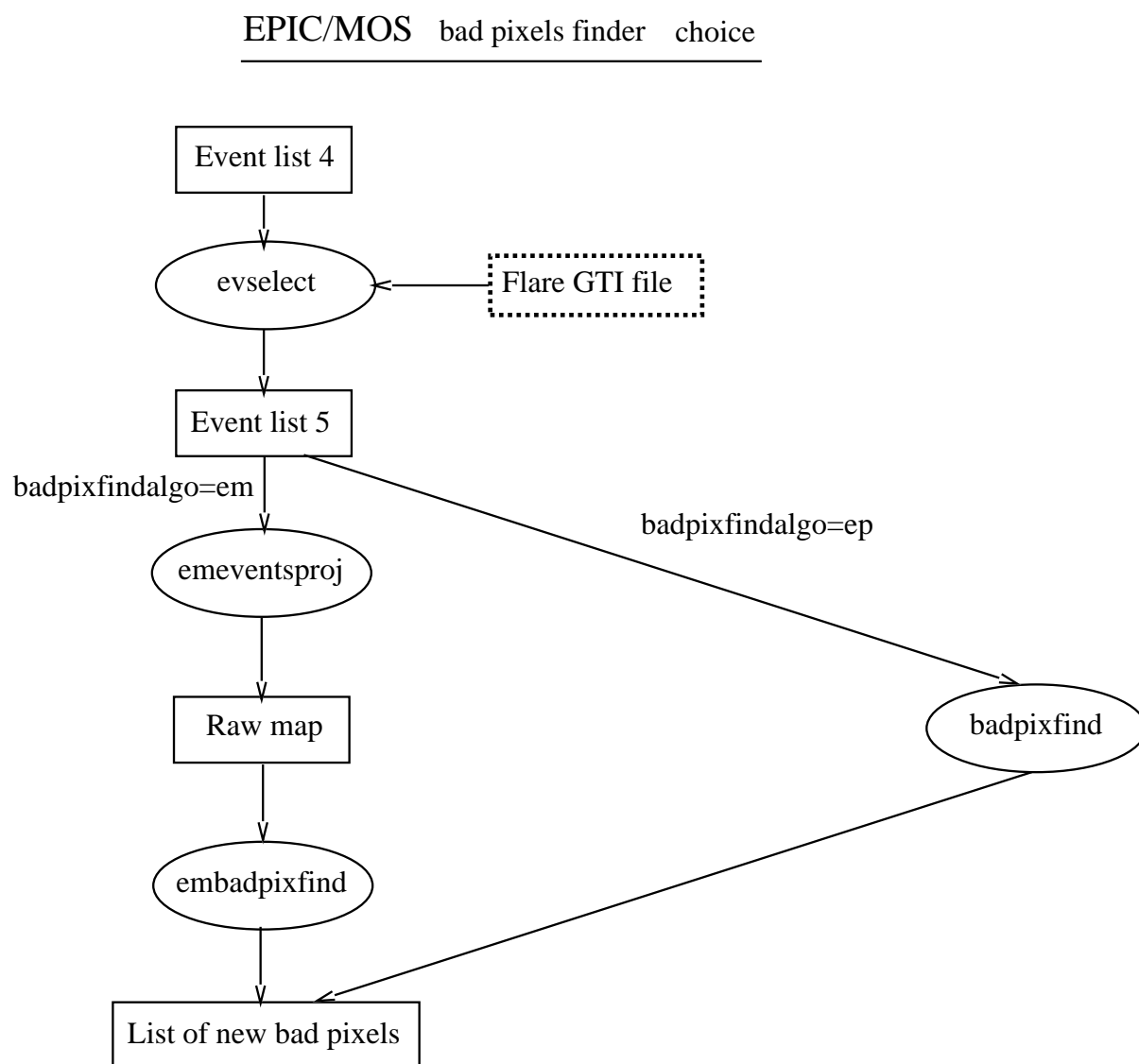


Figure 3: Organisation of the EPIC-MOS chain: Bad pixels search. Same conventions as in Fig 1

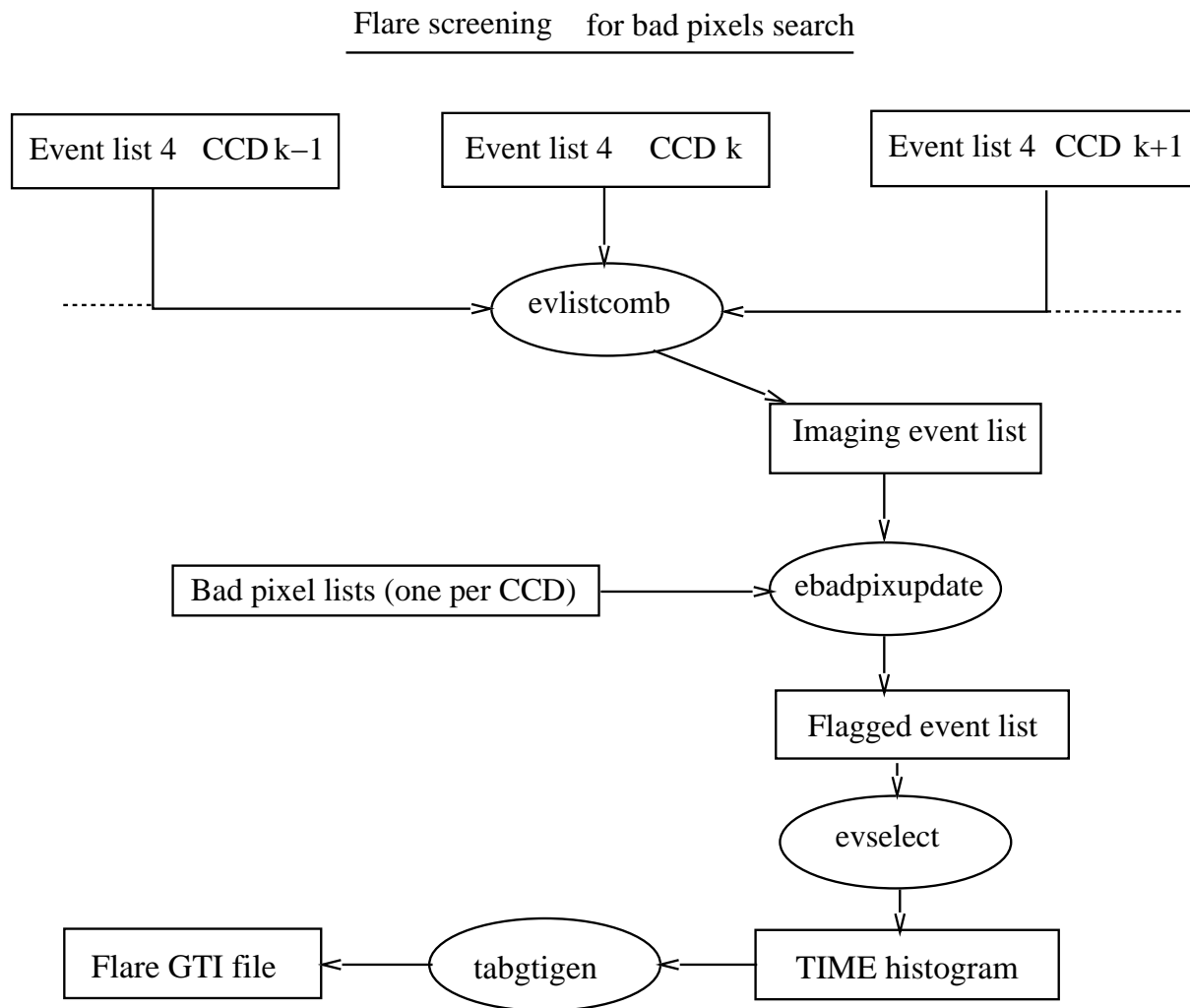
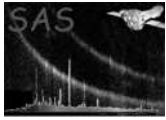
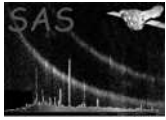


Figure 4: Organisation of the EPIC-MOS chain: Flare screening between first and second bad pixels searches. Same conventions as in Fig 1



flare screening (like in Sect. 3.3) is necessary (Fig 4). The bright pixels (which can perturb the flare screening) are flagged using **ebadpixupdate**. The resulting files are used to generate Good Time Intervals outside flares. Those Good Time Intervals are exposure specific whatever the value of **globalflare**. Then the bad pixel search is run a second time on the data outside flares, in incremental mode.

For **badpixfindalgo**=EM (or not set), the algorithm is called a third time (incrementally) on energies below 500 eV (and after flare screening), unless **lowenerbadpix**=N. This sometimes detects bad pixels more easily, because most appear at low energy.

The resulting bad pixels file is then used by **badpix** in the main pass on the data (Fig 1). Bad pixels declared in the CCF are read as well, and merged with those found in the local search. This second pass restarts just after **emframes**. The **stopafterbadpixfind** parameter allows to stop **emchain** before the main pass, to investigate in detail how the bad pixels detection worked.

If **badpixfindalgo** is set to NO, then the first loop is not done and the bright pixels are read from the CCF.

3.5 Customisation

Many options allow to run **emchain** on a subset of the data, restart from previous output, change the options of constituent tasks.

- The **exposures**, **instruments** and **ccds** parameters allow to run **emchain** on a subset of the data files (select an explicit list of exposures, instruments or CCDs).
- If **addvigweight**=Y, then **evigweight** is called to add a **WEIGHT** column to the events list (for extended source analysis).
- All individual steps in **emchain** except **emframes** may be skipped (**withbadpix**, **withmevents**, **withattcalc**, **withenergy**, **runevlistcomb**, **applyccdgti**, **makeflaregti**). The whole loop over CCDs may be skipped if **runccdloop**=N (the only available functionalities are then those of Fig 1).
- If **runevlistcomb**=N, the merged event files are not built and the output is the collection of individual event and frame files. For example, the event files are called **eventnn.out.mos**, where **nn** is the same as **CCDNR** of the merged file (**10*node+ccd**). To avoid overwriting the files of one exposure with the next, they are renamed **eventnn.out.MkEEEE** where **k** is 1 or 2 and **EEEE** is **EXPIDSTR** (exposure number including **S** or **U**). They are not renamed if only one exposure is processed. Note that all the files must be renamed manually back to ***.out.mos** to allow restarting **emchain** from them (**startfrommodf**=N).
- If **randomize** does not contain the letter **P**, **emevents** is run with **randomizeposition**=N. If **randomize** does not contain the letter **T**, **emevents** is run with **randomizetime**=N. If **randomize** does not contain the letter **E**, **emenergy** is run with **randomizeenergy**=N.
- Parameters may be passed to constituent tasks. The syntax is **'taskname:paramname=soandso'**, where **'paramname'** is the parameter name for task **'taskname'**. This will be passed as **'paramname=soandso'** when calling **'taskname'**.
For example, **'emenergy:useccfdarkframe=Y'** allows using the CCF dark frame for the CCD background correction (this corrects for variations at the pixel scale, whereas the **E₄** data allows to correct for variations on scales larger than 5 pixels).
This syntax does not allow to specify different parameter values on different occurrences of **'taskname'** within **emchain**. The additional parameter will be passed on all occasions.
Parameters specified in that way supersede possible settings of the same parameters by **emchain** itself.



- For calibration purposes (offsets' evolution), or checking optical loading, it can be useful to look at the background (base level) of a CCD. If `writeccdbackground=Y`, then `emchain` writes one file per CCD and per exposure, containing the CCD background (as determined by `emenergy`). This is similar to passing `backgroundset` to `emenergy`, but allows to save all such files under a different name.
- `emchain` normally ignores data obtained with CCD read-out gain set to low ($/10$). This behaviour may be overridden by setting `processlowgain=Y`. Low gain data is then treated as if it was normal data, and included in the merged events file in output, in addition to normal data. Its PI will still be wrong, and the flare screening mechanism will not work normally (because there are very few events at energy more than 100 keV even during flares).
- If `fulloutput=Y`, all columns originally present in the events files (in the ODF) are preserved in the output file (this about doubles the size of the file).
- If intermediate files from a previous call to `emchain` still exist (for example `eventnn.in.mos` files), `emchain` may use them as a starting point instead of the ODF (`startfromodf=N`).

3.6 Examples

`emchain` takes some time to run. It is usually better run as a batch job (at command). Here are a few examples of how to use it. They assume that the `SAS_CCF` environment variable was set to the relevant Calibration Index File.

- Standard run (get calibrated event files from an ODF located in `your_odf_dir`), sending the output to a log file:

```
emchain odf=your_odf_dir > emchain.log 2> emchain.err (sh shell)
emchain odf=your_odf_dir > emchain.log >& emchain.err (csh shell)
```

- Same, but getting the bad pixels from the CCF instead of the data and applying attitude and HK GTIs:

```
emchain odf=your_odf_dir badpixfindalgo=NO filteratt=Y filterhk=Y
```

- Select particular exposure, instrument and CCDs, keep intermediate files and stop at first error:

```
emchain instruments=M2 exposures=S002 ccds='1 3 4' stoponerror=Y \
keepintermediate=Y
```

- Keep events flagged for rejection and all original columns in the ODF, apply user GTI and no TIME randomization:

```
emchain rejectbadevents=N fulloutput=Y randomize='PE' ingtiset=hkgiti.ds
```

- Rebuild the flare GTI files with different settings, keep them exposure specific and add the WEIGHT column:

```
emchain runccdloop=N runeclistcomb=N addvigweight=Y \
globalflare=N flaretimebin=104 flaremaxrate=1.2
```



- Run **attcalc** with fixed attitude:

```
emchain attcalc:attitudelabel=fixed attcalc:fixedra=204.6877 \
      attcalc:fixeddec=-27.6984 attcalc:fixedposangle=59.378
```

- Specify source position manually (instead of using RA_OBJ and DEC_OBJ) for Timing mode:

```
emchain emframes:withsrccoords=Y \
      emframes:srcra=204.6877 emframes:srcdec=-27.6984
```

- Run bad pixels finder on existing intermediate files:

```
rm badpix*.out.mos evmap.in.mos medmap.in.mos
emchain startfromodf=N clobber=N stopafterbadpixfind=Y
```

- Regenerate event files, using new bad pixels files and intermediate files (this will remove the intermediate files on successful output):

```
rm event*.out.mos
emchain startfromodf=N
```

- Relaunch **emchain** after an error which occurred on MOS 2, exposure 4, using already existing intermediate files:

```
rm PooooooooooooM2S004*.FIT
emchain instruments=M2 exposures=4 clobber=N
```

3.7 How to deal with an error

If an error occurred, the very last output of **emchain** will be something like

```
emchain: BEWARE: One or more of the tasks ended in error !
```

You should then look into the log file for a specific message like

```
emchain: BEWARE: That task ended in error !
```

The associated messages may help you understand what happened. If the error occurred in the last exposure, the intermediate files will not be erased, you may also inspect them (if they were erased, rerun **emchain** for the particular instrument and exposure where the error occurred, setting **stoponerror=Y**).

If you think you have found a workaround (editing a file for example), you may relaunch the task which ended in error, duplicating the call written after 'CMD:' in the log file. You may also relaunch **emchain** from the intermediate files (see example above).

If the error is of general significance (not just a corrupted file at your site), feel free to send an Observation Report.



4 Parameters

This section documents the parameters recognized by this task (if any).

| Parameter | Mand | Type | Default | Constraints |
|-----------|------|------|---------|-------------|
|-----------|------|------|---------|-------------|

General parameters

| | | | | |
|-----------------|----|--------|--|------|
| ingtiset | no | string | | none |
|-----------------|----|--------|--|------|

user-supplied good time intervals

| | | | | |
|------------------|----|---------|----|--------|
| filteratt | no | boolean | no | yes/no |
|------------------|----|---------|----|--------|

filter data on bad attitude

| | | | | |
|-----------------|----|---------|----|--------|
| filterhk | no | boolean | no | yes/no |
|-----------------|----|---------|----|--------|

filter data on bad housekeeping

| | | | | |
|-----------------------|----|--------|----|------|
| badpixfindalgo | no | string | EM | none |
|-----------------------|----|--------|----|------|

EP for **badpixfind**, EM for **embadpixfind**, NO for nothing

| | | | | |
|------------------|----|--------|-----|--|
| randomize | no | string | PET | |
|------------------|----|--------|-----|--|

randomize multiswitch (P for position, E for energy, T for time). " for no randomisation at all

| | | | | |
|----------------------|----|---------|----|--------|
| applyflaregti | no | boolean | no | yes/no |
|----------------------|----|---------|----|--------|

apply the proton flare GTI

Selection parameters

| | | | | |
|------------|----|--------|---------|------|
| odf | no | string | SAS_ODF | none |
|------------|----|--------|---------|------|

input directory name (this is a standard SAS parameter)

| | | | | |
|------------------|----|-----------------|-----|------|
| exposures | no | list of strings | all | none |
|------------------|----|-----------------|-----|------|

selected exposures (like S004, or simply 4 if non ambiguous)

| | | | | |
|--------------------|----|-----------------|------|-------|
| instruments | no | list of strings | both | M1/M2 |
|--------------------|----|-----------------|------|-------|

selected instruments

| | | | | |
|-------------|----|------------------|-----|-----|
| ccds | no | list of integers | all | 1-7 |
|-------------|----|------------------|-----|-----|

selected CCDs

Parameters for running part of emchain



| | | | | |
|---|----|---------|-----|--------|
| runccdloop | no | boolean | yes | yes/no |
| loop over CCDs | | | | |
| startfromodf | no | boolean | yes | yes/no |
| analyse raw ODF files | | | | |
| stopafterbadpixfind | no | boolean | no | yes/no |
| stop just after bad pixels detection to investigate | | | | |
| runevlistcomb | no | boolean | yes | yes/no |
| merge the CCD-specific events files | | | | |
| makeflaregti | no | boolean | yes | yes/no |
| build GTI for proton flare rejection | | | | |

Parameters for debugging or calibration

| | | | | |
|--|----|---------|----------|--------|
| rejectbadevents | no | boolean | yes | yes/no |
| reject events with any of the flags in rejectionflag set | | | | |
| rejectionflag | no | string | 762aa000 | none |
| hexadecimal representation of the flags triggering deletion | | | | |
| writeccdbackground | no | boolean | no | yes/no |
| save CCD background for offset calibration (one file per CCD) | | | | |
| processlowgain | no | boolean | no | yes/no |
| process data obtained in low gain read-out mode (as well as normal) | | | | |
| fulloutput | no | boolean | no | yes/no |
| keep all columns in event list (rather than only the ones in SSC products) | | | | |
| applyccdgti | no | boolean | yes | yes/no |
| apply the CCD-specific GTI | | | | |
| keepintermediate | no | boolean | no | yes/no |
| keep intermediate files (or remove them on output) | | | | |
| stoponerror | no | boolean | no | yes/no |
| stop at first error in task call | | | | |
| clobber | no | boolean | yes | yes/no |
| overwrite existing output files | | | | |

Parameters for individual tasks

| | | | | |
|---------------------|----|---------|----|--------|
| withatthkgen | no | boolean | no | yes/no |
|---------------------|----|---------|----|--------|



rerun **atthkgen**

| | | | | |
|---------------|----|------|------|-----|
| atttol | no | real | 0.05 | > 0 |
|---------------|----|------|------|-----|

tolerance for attitude filtering (degrees)

| | | | | |
|-------------------|----|---------|-----|--------|
| withbadpix | no | boolean | yes | yes/no |
|-------------------|----|---------|-----|--------|

run **badpix**

| | | | | |
|---------------------|----|---------|-----|--------|
| withemevents | no | boolean | yes | yes/no |
|---------------------|----|---------|-----|--------|

run **emevents**

| | | | | |
|--------------------|----|---------|-----|--------|
| withattcalc | no | boolean | yes | yes/no |
|--------------------|----|---------|-----|--------|

run **attcalc**

| | | | | |
|---------------------|----|---------|-----|--------|
| withemenergy | no | boolean | yes | yes/no |
|---------------------|----|---------|-----|--------|

run **emenergy**

| | | | | |
|----------------------|----|---------|-----|--------|
| lowenerbadpix | no | boolean | yes | yes/no |
|----------------------|----|---------|-----|--------|

run **embadpixfind** a second time for energies < 500 eV

| | | | | |
|---------------------|----|---------|----|--------|
| addvigweight | no | boolean | no | yes/no |
|---------------------|----|---------|----|--------|

run **evigweight**

| | | | | |
|--------------------|----|---------|-----|--------|
| globalflare | no | boolean | yes | yes/no |
|--------------------|----|---------|-----|--------|

build single flare screening timeseries for the whole observation

| | | | | |
|---------------------|----|------|------|-------|
| flaretimebin | no | real | 52.0 | > 2.6 |
|---------------------|----|------|------|-------|

time bin for flare rejection (s)

| | | | | |
|---------------------|----|------|-----|-----|
| flaremaxrate | no | real | 2.0 | > 0 |
|---------------------|----|------|-----|-----|

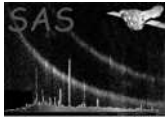
threshold on rate of truncated singles for **tabgtigen** (cts/ks/arcmin²)

The syntax `taskname:parametername=soandso` may be used to pass parameters to individual tasks called by **emchain**. See Sect. 3.5 for details.

Standard SAS parameters

Because **emchain** is a standalone Perl script, it does not deal with the standard SAS parameters (see **taskmain**) in exactly the same way as normal SAS tasks do:

- It does not support the `'-d'` (dialog) option. Actually **emchain** may not be called at all via the SAS GUI.
- It does not support the `'-c'` (noclobber) option because some constituent tasks do not work with that option set. That option is replaced by the **clobber** parameter specific to **emchain**.
- It emulates the `'-h'` (help), `'-m'` (manpage), `'-p'` (param), `'-v'` (version) parameters giving information on **emchain** itself.



- It passes all other standard SAS parameters to its constituent tasks. Specific OAL ('-o') and CAL ('-a', '-f', '-i') options are passed only to the tasks making use of the OAL or CAL, respectively. By default constituent tasks are called with '-w 10' (at most 10 warnings per task).
- All syntaxes (*e.g.* '-o your_odf_dir', 'odf=your_odf_dir', '--odf your_odf_dir') are supported.

Some SAS options are also interpreted at **emchain** level before being passed to its constituent tasks:

- '-V' (verbosity) is used in the same way as the SAS_VERBOSITY environment variable (see Sect. 3.1).
- '-o' (odf) is used to define the directory where the data resides in the same way as the SAS_ODF environment variable (see Sect. 3.1).
- '-i' (ccf) is used in the same way as the SAS_CCF environment variable to append a CALINDEX extension to the output file.

5 Errors

This section documents warnings and errors generated by this task (if any). Note that warnings and errors can also be generated in the SAS infrastructure libraries, in which case they would not be documented here. Refer to the index of all errors and warnings available in the HTML version of the SAS documentation.

odf (*error*)

No or non existing or empty input directory

odffiles (*error*)

No ODF-like file in input directory

lowGain (*warning*)

a CCD was operated in low gain mode. It is scientifically useless and **emchain** will normally not process it. If **processlowgain** is set, it will be processed but the flare screening light curve will be wrong unless this is the central CCD

corrective action: set **processlowgain**=Y if you want that CCD to be processed

badexposure (*warning*)

the event*.out files are incompatible with the requested exposure. The merged events list will not be created. This is possible only when **clobber**=N and event*.out files exist

corrective action: check the event*.out files and rerun

badinstrument (*warning*)

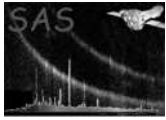
the event*.out files are not MOS files. The merged events list will not be created. This is possible only when **clobber**=N and event*.out files exist

corrective action: check the event*.out files and rerun

protonflare (*warning*)

The GTI fraction after flare screening is less than 10%. It is not applied

corrective action: reassess the flare GTI manually, or change **flaremaxrate** if you wish

**noIN_FOV** (*warning*)

the EXPOSUnn extensions of the merged events file do not contain the IN_FOV keyword. The flare detection cannot proceed

corrective action: rerun emchain on the ODF to regenerate the merged events file

badstring (*warning*)

a keyword does not have the expected length. It is truncated or padded with .. This should not happen on a regular ODF

corrective action: check whether a file is not corrupted in the ODF (you may know which file contains the offending keyword by looking at the messages), and that the substitution is all right

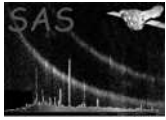
6 Input Files

1. event list files *_Mn*xxE.FIT (one per CCD/node and per exposure), straight from the ODF (n is 1 or 2, xx is IM or TI).
2. auxiliary files *_Mn*AUX.FIT (one per exposure), straight from the ODF.
3. offset/variance files *_Mn*OVE.FIT (one per CCD/node and per mode), straight from the ODF.
4. optionally, a user-supplied GTI file (entered through `ingtiset`) with STDGTI extension.
5. optionally, bad pixels files with BADPIX extension (one per CCD/node and per instrument). They are looked for in the current directory and their names must be P????????DD???BADPIXij00.FIT, where i is the CCD number and j the node number. A file with matching observation and exposure fields is preferred, but any observation and exposure is accepted.

The structure of files in the ODF is described in [1]. The event and offset files in the ODF may be gzipped (end in .gz or .FTZ).

7 Output Files

1. event list files (one per instrument, exposure and per mode), as in the SSC Data Products ICD [2], except they are uncompressed. Their names are PooooooooooooDDUEEEMIEVLI0000.FIT (IMAGING mode) and PooooooooooooDDUEEETIEVLI0000.FIT (TIMING mode). If `addvigweight=Y`, a WEIGHT column is added.
2. timeseries files (one per instrument and per exposure) in RATE format of truncated single events per ks per arcmin², which are used to generate the good time intervals for flare screening. Their names are PooooooooooooDDUEEEFBKTSR0000.FIT. They contain the columns RATE, ERROR, TIME and FRACEXP. If `globalflare=Y`, a global timeseries is created in addition, named PooooooooooooEMX000FBKTSR0000.FIT. In that one FRACEXP may be larger than 1.
3. good time interval files (one per instrument and per exposure) which may be used to select out proton flares in the data. Their names are PooooooooooooDDUEEEFBKGTI0000.FIT. If `globalflare=Y`, a single GTI file is created, named PooooooooooooEMX000FBKGTI0000.FIT.
4. tracking history file PooooooooooooOBX000ATTTSR0000.FIT generated by `atthkgen` (also useful for later tasks like `eexpmap`).



5. attitude GTI file POOOOOOOOOOBOX000ATTGTI0000.FIT generated by **tabgtigen** from the tracking history file.
6. HK GTI files (one per instrument) generated by **hkgtigen**. Their names are POOOOOOOOOOODDX000HK.GTI
7. Optionally (if **writeccdbbackground=Y**), CCD background maps (one per CCD and per exposure) which may be used to check optical loading and the offsets map. Their names are POOOOOOOOOOODDUEEECCDBKGij00.FIT, where i is the CCD number and j the node number.

8 Intermediate Files

1. **framenn.out.mos**: frame file for a given CCD/node in output of **emframes**, where nn is the same as the CCDNR column in the final output file (10*node + CCD).
2. **badpixnn.out.mos**: bad pixels file for a given CCD/node in output of **badpixfind** or **embadpixfind**.
3. **ccdgtinn.in.mos**: GTI file for a given CCD/node in output of **emframes**.
4. **extgti.in.mos**: external GTI file for a given instrument (merged from user, attitude and HK GTIs).
5. **hkgti.in.mos**: external GTI file aligned to frame readout boundaries for the current CCD/node in output of **gtialign**.
6. **gtinn.out.mos**: GTI file for a given CCD/node, intersection of the latter two.
7. **eventnn.in.mos**: input event list file for a given CCD/node, with BADPIX extension appended by **badpix**.
8. **eventnn.out.mos**: event list file for a given CCD/node in output of **emevents**, with BADPIX, OFFSETSO, OFFSETS and EXPOSURE extensions, propagated through **attcalc** and **emenergy**.
9. **merged.img.mos**: merged event list in IMAGING mode in output of **evlistcomb**.
10. **merged.tim.mos**: merged event list in TIMING mode in output of **evlistcomb**.
11. **merged.truncated.mos**: selection of events with truncated energy (for flare screening).

9 Algorithm

```
subroutine emchain
```

```
  Read parameters.
```

```
  if startfromodf then call processOdf
  else if runeclistcomb then call mergeEvents
```

```
  if makeflaregti then
    Loop over the *MIEVLI0000.FIT files
      call makeFlareTS
      if globalflare call mergeTS else call tsToGTI
    end loop
    if globalflare call tsToGTI
```




```
endif

Loop over the *MIEVLI0000.FIT files
  if withflaregti call applyFlareGTI
  if addvigweight call evigweight ineventset=eventfile
end loop

if not keepintermediate then rm -f *.in.mos *.out.mos merged.*.mos

end subroutine emchain

subroutine processOdf

  Set SAS_ODF to odf (for OAL).

  Call atthkgen if no tracking history file or withatthkgen is true.
  Call tabgtigen with expression='!isNull(DAHFPNT) && DAHFPNT<atttol'
  Call hkgtigen if no HK GTI is present.
  gtiin = 'extgti.in.mos'
  Call gtimeerge gtitable=$gtiin on attitude GTI (if filteratt),
    HK GTI (if filterhk) and user GTI (if present)

  Look in odf for ODF files pertaining to selected instrument,
  ending in IME, TIE, RIE or CTE.FIT (possibly .gz or .FTZ).
  Deduce all exposures present.

  Loop over selected exposures
    if badpixfindalgo ne 'NO' then
      call ccdLoop (forbadpixfind=Y)
      call badpixLoop (no flare screening)
      call mergeEvents
      call ebadpixpupdate
      call buildFlareGTI
      call badpixLoop (with flare screening and low energy run)
    endif

    call ccdLoop (forbadpixfind=N)
    if runeclistcomb then call mergeEvents
  end loop over exposures

end subroutine processOdf

subroutine ccdLoop

  Loop over selected CCDs and nodes

  Identify event file name event0 ending in IME, TIE, RIE or CTE.FIT.
  Deduce ccd and node.

  aux = substring($event0 - last 9 characters) // '00AUX.FIT'
  gtiout = 'gti' // node // ccd // '.out.mos'
  frameout = 'frame' // node // ccd // '.out.mos'
  emframes auxiliaryset=frame.in odfeventset=$event0 \
    frameset=$frameout writegtiset=Y outgtiset=$gtiout
  if ($gtiin exists) then
```



```
flagbadtimes=Y ingtiset=$gtiin

if (not processlowgain and GAIN_CCD='LOW') next

bad = 'badpix' // node // ccd // '.out.mos'
if $bad does not exist then
    bad = 'P*' // instrument // '*BADPIX' // ccd // node // '00.FIT'

if withbadpix and not forbadpixfind then
    badpix eventset=$event0 withoutset=Y outset=event.in windowfilter=Y
    if ($bad exists) then
        getuplnkbadpix=Y getotherbadpix=N getnewbadpix=Y badpixset=$bad
    else
        cp $event0 event.in.mos
    endif

eventout = 'event' // node // ccd // '.out.mos'
off = odf // * // instrument // * // ccd // node // 'OVE.FIT'
emevents withframeset=Y frameset=$frameout odfeventset=event.in \
    eventset=$eventout
if ($off exists) then withoffvarsets=Y offvarsets=$off
if not randomizeP then randomizeposition=N
if randomizeT then randomizetime=Y
if forbadpixfind then analysepatterns=N flagbadpixels=N \
    splitdiagonals=N randomizeposition=N

if ($gtiin exists) then
    gtialign gtitable=$gtiin:STDGTI eventset=$eventout \
        outset=hkgti.in.mos
    extname = 'STDGTI' // node // ccd
    gtimerge tables="hkgti.in.mos ccdgti.in.mos" mergemode=and \
        gtitable=$gtiout:$extname

if withattcalc and not forbadpixfind then
    attcalc eventset=$eventout

emenergy ineventset=$eventout
if not imaging mode then getccdbkg=N
if not randomizeE then randomizeenergy=N
if forbadpixfind then correctcti=N correctgain=N randomizeenergy=N
bkg = 'P'//obsid//instrument//expid//'CCDBKG'//ccd//node//'00.FIT'
if writeccdbbackground then backgroundset=$bkg

if rejectbadevents or forbadpixfind then
    evselect table=$eventout destruct=Y keepfilteroutput=Y \
        expression="(FLAG & 0x$rejectionflag) == 0"

end loop over CCDs and nodes

end subroutine ccdLoop

subroutine badpixLoop

    Loop over selected CCDs and nodes
```



```
eventout = 'event' // node // ccd // '.out.mos'
bad = 'badpix' // node // ccd // '.out.mos'

evselect table=$eventout withfilteredset=Y filteredset=event.in.mos \
    keepfilteroutput=Y destruct=Y writedss=Y updateexposure=Y \
    expression="TIME in GTI($gtiflare)"

if badpixfindalgo == 'EM' then
    emeventproj eventset=event.in.mos rejectbadevents=Y \
        evimageset=evmap.in.mos
    embadpixfind evimageset=evmap.in.mos badpixset=$bad

    if (lowenerbadpix) select PHA < 150 and run again incrementally
else
    badpixfind eventset=event.in.mos thresholdlabel=rate \
        badpixset=$bad \
        hithresh=0.005 narrowerthanpsf=3.0 backgroundrate=1.E-5
endif

end loop over CCDs and nodes

if stopafterbadpixfind stop

end subroutine badpixLoop

subroutine mergeEvents

evlistcomb eventsets='event*.out.mos' imagingset=merged.img.mos \
    timingset=merged.tim.mos maintable='EVENTS OFFSETS'
if fulloutput then
    emosingcolnames="TIME RAWX RAWY DETX DETY X Y PHA PI FLAG PATTERN
        FRAME ENERGYE1 ENERGYE2 ENERGYE3 ENERGYE4 PERIPIX OFFSETX OFFSETY"
    emosingcoltypes="double int16 int16 int16 int16 int32 int32 int16
        int16 int32 int8 int32 int16 int16 int16 int16 int8 int16 int16"
endif

if applyccdgti then
    Loop over gti*.out.mos files
    expr = expr // '|| (CCDNR== ' // node // ccd // ' && GTI($gtiout,TIME))'
endif

eventim = 'P' // obsid // instrument // expid // 'MIEVLI0000.FIT'
evselect table=merged.img.mos withfilteredset=Y filteredset=$eventim \
    expression=$expr destruct=Y keepfilteroutput=Y

fparkey "EPIC MOS IMAGING MODE EVENT LIST" $eventim[0] CONTENT \
    add=Y insert=DATE"
fappend $sasccf[CALINDEX] $eventim

if (merged.tim exists) then
    eventti = 'P' // obsid // instrument // expid // 'TIEVLI00001.FIT'
    evselect table=merged.tim.mos withfilteredset=Y filteredset=$eventti \
        expression=$expr destruct=Y keepfilteroutput=Y
    fparkey "EPIC TIMING MODE EVENT LIST" $eventti[0] CONTENT \
        add=Y insert=DATE"
```



```
        fappend $sasccf[CALINDEX] $eventti
    endif

end subroutine mergeEvents

subroutine makeFlareTs
    expr = "(PATTERN==0) && ((FLAG & 0x762b8000) == 0) && #XMMEA_22"
    flarets = 'P' // obsid // instrument // expid // 'FBKTSR0000.FIT'
    check that expected counts per bin in quiet conditions is > 10,
        otherwise increase $flaretimebin
    evselect table=$eventim expression=$expr updateexposure=N \
        withrateset=Y rateset=$flarets timebinsize=$flaretimebin \
        timecolumn=TIME maketimecolumn=Y makeratecolumn=Y
    add FRACEXP column (currently done by looking at full timeseries)
    divide by CCD area (IN_FOV keyword) and FRACEXP
end subroutine makeFlareTs

subroutine mergeTs
    globts = 'P' // obsid // 'EMX000FBKTSR0000.FIT'
    if $globts exists then
        multiply by CCD area and FRACEXP
        merge columns of $flarets and $globts:
        RATE      = RATE1 + RATE2
        ERROR     = SQRT(ERROR1**2 + ERROR2**2)
        FRACEXP   = FRACEXP1 + FRACEXP2
        divide by CCD area and FRACEXP
    endif else then
        cp $flarets $globts
    endelse
end subroutine mergeTs

subroutine tsToGTI
    gtiflare = timeseries prefix // 'FBKGTI0000.FIT'
    tabgtigen table=$flarets expression="RATE<$flaremaxrate" \
        gtiset=$gtiflare
    evselect table=$gtiflare writedss=N updateexposure=N keepfilteroutput=Y \
        expression="(STOP - START) > 1.5*$flaretimebin"
end subroutine tsToGTI

subroutine applyFlareGTI
    expr = "GTI($gtiflare,TIME)"
    evselect table=$eventim destruct=Y keepfilteroutput=Y expression=$expr
    evselect table=$eventti destruct=Y keepfilteroutput=Y expression=$expr
end subroutine applyFlareGTI
```

10 Comments

The script does not use the SAS' parameter and error interfaces, to allow easy modifications by users.



11 Future developments

The chain will adapt to the evolution of its constituents and to the organisation of the pipeline.

References

- [1] ESA. XMM Interface Control Document: Observation and Slew Data Files (XSCS to SSC) (SciSIM to SOCSIM). Technical Report XMM-SOC-ICD-0004-SSD Issue 2.5, ESA/SSD, June 2000. Found at the URL: ftp://astro.estec.esa.nl/pub/XMM/documents/odf_icd.ps.gz.
- [2] SSC. XMM Survey Science Centre to Science Operations ICD for SSC Products. Technical Report XMM-SOC-ICD-0006-SSC Issue 2.1, SSC, Mar 2000.